CLAIMS

What is claimed is:

1. A method for forming a supported metal-containing powder, the method comprising:

(i) forming a dispersion of a particulate support in a solution, the solution comprising a solvent and a dissolved metal, wherein the volumetric ratio of the particulate support to the solvent is at least about 1:10;

(ii) removing heat from the dispersion to precipitate the dissolved metal from the solution onto the particulate support; and

(iii) after step (ii), separating the particulate support from the solution to yield the supported metal-containing powder, the powder comprising the particulate support and a precipitated metal thereon.

2. The method of claim 1 further comprising reducing the precipitated metal on the particulate support.

3. The method of claim 2 wherein the precipitated metal is reduced to its metallic oxidation state.

4. The method of claim 1 wherein the particulate support used to form the dispersion comprises a pre-deposited material selected from the group consisting of a pre-deposited metal compound, a pre-deposited metal in its metallic oxidation state, and combinations thereof, the method further comprising forming an alloy on the particulate support, the alloy comprising metals derived from the pre-deposited material and the precipitated metal.

5. The method of claim 1 wherein the dispersion is formed using a solution comprising a first dissolved metal and a second dissolved metal, both of which are precipitated on the particulate support upon removal of heat from said dispersion.

6. The method of claim 5 further comprising forming an alloy on the particulate support, the alloy comprising metals derived from the first and second precipitated metals.

7. The method of claim 1 wherein the dispersion is within a container having an exterior and heat is removed from the dispersion in step (ii) by contacting the exterior of the container with a cooling medium.

8. The method of claim 7 wherein in step (iii) the separated solution is removed from the container.

9. The method of claim 7 wherein the container has a cover that allows for a gas but substantially no particulate support to exit therefrom.

10. The method of claim 1 wherein the volumetric ratio of the particulate support to the solvent is at least about 1:8.

11. The method of claim 1 wherein the volumetric ratio of the particulate support to the solvent is at least about 1:5.

12. The method of claim 1 wherein the volumetric ratio of the particulate support to the solvent is at least about 1:2.

13. The method of claim 1 wherein the dispersion has a viscosity that is least about 5,000 mPa•s.

14. The method of claim 1 wherein the particulate support are uniformly dispersed in the solution.

15. The method of claim 1 wherein the dispersion is a suspension.

16. The method of claim 1 wherein the removal of heat from the dispersion freezes the solution.

17. The method of claim 1 wherein the separation of the particulate support from the solution is by filtration, evaporation, sublimation, or a combination thereof.

18. The method of claim 1 wherein the separation of the particulate support from the solution is by freeze-drying.

19. A method for forming a supported metal-containing powder, the method comprising:

(i) forming a dispersion of a particulate support in a solution, the solution comprising a solvent and a dissolved metal;

(ii) removing heat from the dispersion to precipitate the dissolved metal from the solution onto the particulate support and to freeze the solution, wherein the heat is removed from the dispersion by contacting a container containing the dispersion with a cryogenic liquid; and

(iii) after step (ii) separating the particulate support from the solution by freeze-drying to yield the supported metal-containing powder, the powder comprising the particulate support and a precipitated metal thereon.

20. The method of claim 19 further comprising reducing the precipitated metal on the particulate support.

21. The method of claim 20 wherein the precipitated metal is reduced to its metallic oxidation state.

22. The method of claim 20 wherein the precipitated metal on the particulate support has a deposit size that is less than about 20 nm.

23. The method of claim 20 wherein the precipitated metal on the particulate support has a deposit size that is between about 2 and about 3 nm.

24. The method of claim 19 wherein steps (i) and (iii) are also performed in the container.

25. The method of claim 24 wherein the container has a cover that allows for a gas but substantially no particulate support to exit therefrom.

26. The method of claim 19 wherein the solvent is selected from the group consisting of water, an alcohol, acetic acid, carbon tetrachloride, ammonia, 1,2 dichloroethane, N,N-dimethylformamide, and formamide.

27. The method of claim 19 wherein the solvent comprises water.

28. The method of claim 19 wherein the dissolved metal is from a metal-containing compound selected from the group consisting of a metal sulfate, a metal nitrate, a metal nitrite, a metal oxalate, metal acetate, and metal formate.

29. The method of claim 19 wherein the dissolved metal is from an inorganic metal-containing compound.

30. The method of claim 19 wherein the particulate support are selected from the group consisting of a particulate carbon support and a particulate electrically conductive polymer support.

31. The method of claim 19 wherein the particulate support used to form the dispersion comprises a pre-deposited material selected from the group consisting of a pre-deposited metal compound, a pre-deposited metal in its metallic oxidation state, and combinations thereof, the method further comprising forming an alloy on the particulate support, the alloy comprising metals derived from the pre-deposited material and the precipitated metal.

32. The method of claim 31 wherein the loading of the pre-deposited material on the particulate support is up to about 90 weight percent.

33. The method of claim 31 wherein the loading of the pre-deposited material on the particulate support is between about 5 and about 60 weight percent.

34. The method of claim 31 wherein the pre-deposited material has a deposit size that is less than about 20 nm.

35. The method of claim 31 wherein the pre-deposited material has a deposit size that is between about 2 and about 3 nm.

36. The method of claim 31 wherein the alloy has a deposit size that is less than about 20 nm.

37. The method of claim 31 wherein the alloy has a deposit size that is between about 2 and about 3 nm.

38. The method of claim 19 wherein the dispersion is formed using a solution comprising a first dissolved metal and a second dissolved metal, both of which are precipitated on the particulate support upon removal of heat from said dispersion.

39. The method of claim 38 further comprising forming an alloy on the particulate support, the alloy comprising metals derived from the first and second precipitated metals.

40. The method of claim 19 wherein a post-deposited material is deposited onto the particulate support after step (iii), the post-deposited material being selected from the group consisting of a pre-deposited metal compound, a pre-deposited metal in its metallic oxidation state, and combinations thereof, the method further comprising forming an alloy on the particulate support, the alloy comprising metals derived from the post-deposited material and the precipitated metal.

41. The method of claim 19 wherein the particulate support has an average size of at least about 100 nm.

42. The method of claim 19 wherein the particulate support has an average size that is between about 200 and about 300 nm.

43. The method of claim 19 wherein the particulate support comprises between about 1 and about 30 weight percent of the dispersion.

44. The method of claim 19 wherein the particulate support comprises between about 1 and about 10 weight percent of the dispersion.

45. The method of claim 19 wherein step (ii) comprises cooling the dispersion at a rate of at least about 20 °C/minute.

46. The method of claim 19 wherein step (ii) comprises cooling the dispersion at a rate between about 50 and about 100 °C/minute.

47. The method of claim 19 wherein the cryogenic liquid is at a temperature that is at least about 20 °C below the freezing point of the solvent portion.

48. The method of claim 19 wherein the cryogenic liquid is selected from the group consisting of liquid nitrogen, liquid hexane, liquid helium, liquid argon, an ice water/hydrous calcium chloride mixture, an acetone/dry ice mixture, and a diethyl ether/dry ice mixture.

49. A method of forming a carbon supported platinum alloy, the method comprising:

(i) forming a dispersion of a carbon supported platinum in a solution, the carbon supported platinum comprising a particulate carbon support and platinum in its metallic oxidation state thereon, and the solution comprising a solvent and a dissolved non-platinum metal;

(ii) removing heat from the dispersion to precipitate the dissolved non-platinum metal from the solution onto the carbon supported platinum and to freeze the solution, wherein the heat is removed from the dispersion by contacting a container containing the dispersion with a cryogenic liquid;

(iii) separating the frozen solution and the carbon supported platinum by freeze-drying; and

(iv) after step (iii) forming an alloy on the particulate carbon support to yield the carbon supported platinum alloy, the carbon supported platinum alloy comprising the particulate carbon support and the platinum and the non-platinum metal derived from the precipitated non-platinum metal.